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EE193 – Project Final Report

Movement Detection using Contiki and Android

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Movement Detection using Contiki and Android
Part I - Contiki

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1 Introduction

1.1 Falling detection

Falling is a major hazard for body injury or death if not treated timely. Elderly people are vulnerable for falling because of the weakness of their body.

As the MEMS technology progresses rapidly, the low power, inexpensive and high precision accelerometers have become more and more popular and is widely used for vehicles, smartphones. Some of the newly developed accelerometers have 3-axis detections and can be used to detect different pattern of movement on wearable devices. For example, the ADXL345 accelerometer developed by Analog Devices[1].

1.2 6LoWPAN

Internet has profoundly changed the way people communicate. Internet is based on the TCP/IP protocol suite. With TCP/IP protocol suite, a lot of heterogeneous networks can talk with each other.

IPv6 is the next generation of Internet that greatly expands the current IPv4 based protocols. As IPv4 has only 32 bit addresses, it cannot deal with the exponential expansion of Internet, especially the demand of Internet of Things of connecting a large number of nodes. IPv6 has 128 bit addresses and can support nearly infinite number of connected nodes.

The TCP/IP protocol is also demanding for the embedded systems. It often requires an operating system to run the full protocol suite, and it needs more resources than most of the inexpensive, low power embedded systems. Nonetheless, the benefit of running TCP/IP protocol suite on those systems is great as it is the most widely supported and expandable network protocol.

The 6LoWPAN is an IETF standard that tries to resolve this conflict. It is well suited to resource limited embedded systems that can be used for Internet of Things. 6LoWPAN has a similar layered structure as the TCP/IP protocol suite, as shown in Figure 1:

1.3 Contiki

Contiki is open source software: Contiki can be freely used both in commercial and non-commercial systems and the full source code is available.

Contiki provides powerful low-power Internet communication. Contiki supports fully standard IPv6 and IPv4, along with the recent low-power wireless standards: 6LoWPAN, RPL, CoAP. With Contiki's ContikiMAC and sleepy routers, even wireless routers can be battery-operated.

Contiki runs on a range of low-power wireless devices, many of which can be easily purchased online[2]. For this project, we use the Zolertia Z1 motes which are supported by Contiki.

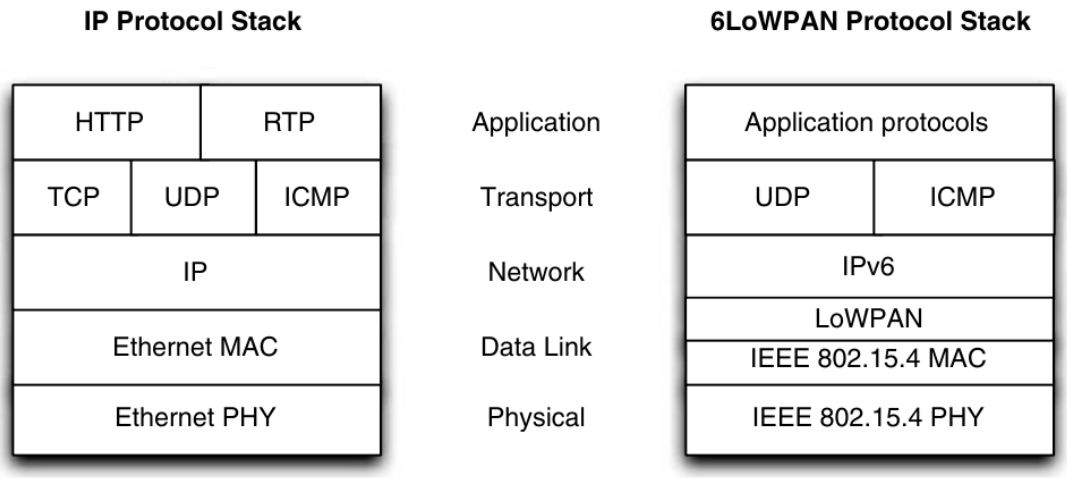

Figure 1: IP and 6LoWPAN protocol stacks

1.4 Z1 motes

The Zolertia Z1 is a low-power wireless sensor network mote. It features a second generation MSP430F2617 low power microcontroller with[3]:

- a 16-bit RISC CPU @16 MHz clock speed.
- built-in clock factory calibration.
- 8 KB RAM.
- 92 KB Flash memory.
- IEEE 802.15.4 compliant CC2420 transceiver operates at 2.4 GHz with an effective data rate of 250 Kbps.
- a digital programmable accelerometer ADXL345.
- a digital temperature sensor TMP102.

Although Z1 has 92kB Flash memory, only the addresses below 64kB can be used now because of the limitations of compiler or boot loader.

2 Project network configuration

2.1 Basic configuration

We need to access the Z1 motes on the Internet in order to let them communicate with the web server.

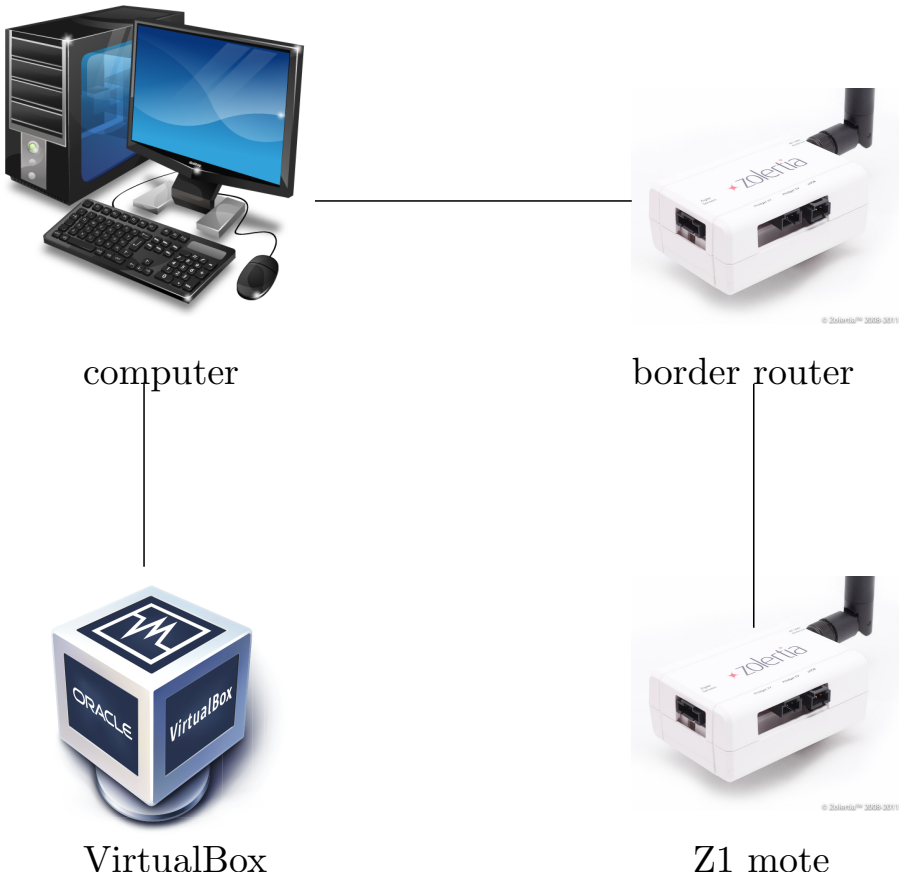

Figure 2: Project configuration

The basic configuration is shown in Figure 2.

The whole system includes:

1. One computer that runs Linux operating system.
2. An Oracle VirtualBox virtual machine runs on the Linux computer.
3. One Z1 mote that is connected to the computer using a USB cord. It is used as a border router.
4. One Z1 mote wirelessly connected to the border router.

We install a Oracle VirtualBox virtual machine that runs Instant Contiki on the Linux computer. The Instant Contiki is a Contiki development environment that consists of:

1. 32 bit Ubuntu 12.04 Linux operating system.
2. MSPGCC 4.7.0 toolchain for compiling, system library, and linking.
3. OpenJDK for compiling and running Cooja simulator.
4. Python for running Contiki tools.

5. GNU make for project management.
6. Contiki 2.6 and 2.7 source code.
7. Cooja simulator.

2.2 Configure the virtual machine network

The best way to access the virtual machine remotely is configuring the virtual machine network to bridged mode. We use VirtualBox as our virtual machine. The default network configuration is NAT mode. Go to Devices-Network-Network Settings...-Adapter 1, beside "Attached to:", choose "Bridged Adapter". Beside "Name", choose the interface that you use to get online for your computer. Normally it is "wlan0" for wireless and "eth0" for wired. Also check the "Cable Connected". This should be done before running the Ubuntu 12.04 guest OS.

2.3 Setting up virtual machine guest OS

Z1 motes are accessed through the border router. In Cooja we use the SLIP protocol to establish a point-to-point connection to the Internet by executing:

```
cd /home/user/contiki/examples/ipv6/rpl-border-router
make connect-router-cooja TARGET=sky
```

It adds a virtual network interface called `tun0`. At the end of this command we are providing a prefix of `aaaa::1/64`, which enables the device to pick its own IPv6 address using Stateless Address Auto-configuration (SLAAC). It is important to note that this means the prefix needs to use a /64 mask.

When first connected to a network, a host sends a link-local router solicitation multicast request for its configuration parameters; routers respond to such a request with a router advertisement packet that contains Internet Layer configuration parameters.

On Ubuntu 12.04 in the virtual machine, edit file `/etc/sysctl.conf` by running

```
sudo nano /etc/sysctl.conf
```

uncomment the line (remove the starting `#`)

```
net.ipv6.conf.all.forwarding=1
```

to enable IPv6 packet forwarding. Then run

```
sudo sysctl -p
sudo nano /etc/radvd.conf
```

This creates an empty file. Copy

```
interface eth0 {
  ## (Send advertisement messages to other hosts)
  AdvSendAdvert on;
  ## IPv6 subnet prefix
  prefix bbbb::/64 {
    AdvOnLink on;
    AdvAutonomous on;
  };
};
```

to the file and execute:

```
sudo /etc/init.d/radvd start
```

It then starts normally.

After radvd is started, all computers on the same LAN with our computer that Cooja runs receive the advertised router information and auto-configure their IPv6 addresses with prefix `bbbb::`. Run

```
/sbin/ifconfig eth0
```

and write down the IPv6 address with prefix `bbbb`. Mine is

```
bbbb::a00:27ff:fe8d:4867
```

2.4 Setting up remote computer OS

Next we set up the remote computer OS. As our virtual machine network is in bridged mode, our host computer is considered a remote computer on LAN. We cannot directly access the motes because we do not have the routing information yet.

We plan to add a new route on one computer in the LAN. First we check if our computer has received the advertised address.

Check the network interface card by `/sbin/ifconfig eth0`, and get

```
zengxu@desktop1:~$ /sbin/ifconfig eth0
eth0      Link encap:Ethernet  HWaddr d4:3d:7e:97:22:90
          inet addr:192.168.0.104  Bcast:192.168.0.255  Mask:255.255.255.0
          inet6 addr: 2601:6:7e80:aa9:d63d:7eff:fe97:2290/64 Scope:Global
          inet6 addr: fd5c:3ea0:7a43::6ed/128 Scope:Global
          inet6 addr: fe80::d63d:7eff:fe97:2290/64 Scope:Link
          inet6 addr: fd5c:3ea0:7a43:0:d63d:7eff:fe97:2290/64 Scope:Global
          inet6 addr: bbbb::d63d:7eff:fe97:2290/64 Scope:Global
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:327 errors:0 dropped:0 overruns:0 frame:0
          TX packets:337 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:68258 (66.6 KiB)  TX bytes:48365 (47.2 KiB)
```

So we get the new address, which is `bbbb::d63d:7eff:fe97:2290/64`.

As we need a route to access the `aaaa::/64` network and that can only be forwarded by the bridged `eth0` interface in our virtual machine, We manually add the routing to the network `aaaa::/64` used by the 6LoWPAN network.

```
sudo /sbin/route -A inet6 add aaaa::/64 gw bbbb::a00:27ff:fe8d:4867
```

which means we use the `eth0` interface in the virtual machine as our gateway to `aaaa::/64` network.

Do a ping6 to test it:

```
zengxu@desktop1:~$ ping6 aaaa::212:7401:1:101
PING aaaa::212:7401:1:101(aaaa::212:7401:1:101) 56 data bytes
64 bytes from aaaa::212:7401:1:101: icmp_seq=1 ttl=63 time=8.63 ms
64 bytes from aaaa::212:7401:1:101: icmp_seq=2 ttl=63 time=8.54 ms
64 bytes from aaaa::212:7401:1:101: icmp_seq=3 ttl=63 time=8.23 ms
64 bytes from aaaa::212:7401:1:101: icmp_seq=4 ttl=63 time=7.89 ms
```

2.5 Analyze packets using Wireshark

In Cooja, click "Tools-Radio Messages-Analyzer", choose "6LoWPAN Analyzer with PCAP". This will generate a PCAP file which is the traffic log of all the packets. After finishing running your simulation, open Wireshark, then open the PCAP file under the directory `/home/user/contiki/tools/build`. We can then use Wireshark to check every packet with detailed information on all layers.

For the neighbor discovery and RPL protocols, Wireshark can be used to analyze the ICMPv6 RPL Control packets, for example, DIS, DIO, DAO packets.

3 Compiling a Contiki program

3.1 Contiki version

There are 2 Contiki versions in the Instant Contiki virtual machine. 2.6 in `/home/user/contiki` and 2.7 in `/home/user/contiki-2.7`.

3.2 GCC compiler

We use GCC to compile Contiki. Please note that for the MSP430 targets, the vanilla GCC only supports it in version 4.9 or higher. There is an MSPGCC project that provides MSP430 target support for old versions like 4.6.3 or 4.7.0. Also only MSPGCC 4.7.0 or higher supports large memory space (above 64 kB). Also, compiling with MSPGCC 4.6.3 does not get the correct serial port output.

3.3 GNU make

The Contiki project uses `GNU make` to manage the compiling process. Usually the makefile is called `Makefile`. One makefile can include other makefiles by using:

```
include filenames
```

3.3.1 Rules

The basic structure of a makefile is one or multiple rules like the following:

```
target: prerequisites
      recipe
```

Each recipe must begin with a tab character. This syntax tells `make` that the characters that follow the tab are to be passed to a subshell for execution. The recipe of a rule consists of one or more shell command lines to be executed, one at a time, in the order they appear.

There are several different kinds of rules:

Explicit rules indicate a specific target to be updated if it is out of date with respect to any of its prerequisites.

Pattern rules uses wildcards instead of explicit filenames.

Implicit rules are either pattern rules or suffix rules found in the rules database built-in to `make`.

Static rules are like regular pattern rules except they apply only to a specific list of target files.

Suffix rules were `make`'s original means for writing general rules. They are considered obsolete in `GNU make`.

The order of rules is not significant, except for determining the default goal: the target for make to consider, if you do not otherwise specify one. The default goal is the target of the first rule in the first makefile. If the first rule has multiple targets, only the first target is taken as the default.

`GNU make` does its work in two distinct phases. During the first phase it reads all the makefiles, included makefiles, etc. and internalizes all the variables and their values, implicit and explicit rules, and constructs a dependency graph of all the targets and their prerequisites. During the second phase, make uses these internal structures to determine what targets will need to be rebuilt and to invoke the rules necessary to do so.

When invoking `make`, you usually specify a target as an argument. If you do not specify an argument, then `make` will use the default target as the argument. The default is the first target that is not started with a dot. By convention, we use `all` target, although it could be anything.

3.3.2 Variables

You can define your own variables in your makefile. Variables are all global, and they can only be used after definition.

3.3.3 Automatic variables

Automatic variables are set by `make` after a rule is matched. Some of the common automatic variables:

`$<` The name of the first prerequisite.
`$@` The file name of target of the rule.
`$^` The name of all the prerequisites, with spaces between them.

Its very important that you recognize the limited scope in which automatic variable values are available: they only have values within the recipe. In particular, you cannot use them anywhere within the target list of a rule; they have no value there and will expand to the empty string. Also, they cannot be accessed directly within the prerequisite list of a rule. A common mistake is attempting to use `$@` within the prerequisites list; this will not work. However, there is a special feature of GNU make, secondary expansion, which will allow automatic variable values to be used in prerequisite lists.

3.3.4 Special variables

Some special variables are used:

`MAKEFILE_LIST` Contains the name of each makefile that is parsed by make, in the order in which it was parsed.

3.3.5 Source code path

The general search path `VPATH` is used to specify the paths that `make` searches when looking for source code. We can also use `vpath` to be more fine grained and efficient:

```
vpath pattern directory-list
```

3.3.6 Pattern rules

If you write multiple pattern rules with exactly the same target and prerequisites (not necessarily the same recipe) then only the last one will be executed. But `make` does not report any errors in such situations.

If only the target is the same then only the first one that can be executed (e.g. the prerequisites exist) is executed.

3.3.7 Implicit rules

Implicit rules tell `make` how to use customary techniques so that you do not have to specify them in detail when you want to use them. For example, there is an implicit rule for C compilation. File names determine which implicit rules are run. For example, C compilation typically takes a .c file and makes a .o file. So make applies the implicit rule for C compilation when it sees this combination of file name endings.

To allow `make` to find a customary method for updating a target file, all you have to do is refrain from specifying recipes yourself. Either write a rule with no recipe, or dont write a rule at all. Then `make`

will figure out which implicit rule to use based on which kind of source file exists or can be made.

In general, `make` searches for an implicit rule for each target, and for each double-colon rule, that has no recipe. A file that is mentioned only as a prerequisite is considered a target whose rule specifies nothing, so implicit rule search happens for it.

Some of the mostly commonly used implicit rules:

Linking a single object file `n` is made automatically from `n.o` by running the linker via the C compiler as:

```
$(CC) $(LDFLAGS) n.o $(LOADLIBES) $(LDLIBS)
```

Compiling C programs `n.o` is made automatically from `n.c` with:

```
$(CC) $(CPPFLAGS) $(CFLAGS) -c
```

3.3.8 Debugging

Invoke `make` with `-n` argument to just print out the commands without actually executing them. The `-p` argument dumps the internal database including all the variables. The `--debug` option can also be used for debugging.

3.4 Z1 websense makefile

3.4.1 Generating target ELF file

We take the `examples/z1/ipv6/z1-websense/Makefile` as an example. This is the makefile we will use for our movement detection. We use the default rule `all` to compile, link and generate the final ELF file `z1-websense.z1`. Its prerequisite is `z1-websense`:

```
1  all: z1-websense
2
3  CONTIKI=../../../..
4
5  WITH_UIP6=1
6  UIP_CONF_IPV6=1
7
8  SMALL=1
9
10 APPS += webserver webbrowser
11
12 CFLAGS += -DPROJECT_CONF_H=\"project-conf.h\"
13 CONTIKI_SOURCEFILES += wget.c
14 PROJECTDIRS += ../../../ipv6/rpl-border-router
15 PROJECT_SOURCEFILES += httpd-simple.c
16
17 include £(CONTIKI)/Makefile.include
```

```
18
19 $(CONTIKI)/tools/tunslip6:        $(CONTIKI)/tools/tunslip6.c
20         (cd $(CONTIKI)/tools && $(MAKE) tunslip6)
21
22 connect-router:        $(CONTIKI)/tools/tunslip6
23         sudo $(CONTIKI)/tools/tunslip6 aaaa::1/64
24
25 connect-router-cooja:        $(CONTIKI)/tools/tunslip6
26         sudo $(CONTIKI)/tools/tunslip6 -a 127.0.0.1 aaaa::1/64
```

It sets `UIP_CONF_IPV6=1`, which includes IPv6 support in uIP protocol stack.

This file includes other makefiles. The included makefile list:

```
MAKEFILE_LIST :=  Makefile \
../../../../Makefile.include \
Makefile.target \
../../../../core/net/rime/Makefile.rime \
../../../../core/net/mac/Makefile.mac \
../../../../core/net/Makefile.uip \
../../../../core/net/rpl/Makefile.rpl \
../../../../apps/webserver/Makefile.webserver \
../../../../apps/webbrowser/Makefile.webbrowser \
../../../../platform/z1/Makefile.z1 \
../../../../platform/z1/Makefile.common \
../../../../cpu/msp430/Makefile.msp430
```

One major makefile is `Makefile.include`. It sets several variables:

1. Checks if saved target file `Makefile.target` exists. If it exists then uses the variable `TARGET` defined in it. The variables `$(TARGET)=z1` as we set in the target makefile.
2. Checks if saved custom file `Makefile.z1.defines` exists. If it exists then uses the definitions there.
3. Checks whether the OS is Windows or Mac OS X/Linux/UNIX and set the variable `HOST_OS` accordingly.
4. Sets `OBJECTDIR=obj_z1`.
5. Includes `core/net/rime/Makefile.rime`.
6. Includes `core/net/mac/Makefile.mac`.
7. Includes `core/net/Makefile.uip`.
8. Includes `core/net/rpl/Makefile.rpl`.
9. Sets `target_makefile` to `platform/z1/Makefile.z1` and includes it. It then includes `platform/z1/Makefile.comm` further includes `cpu/msp430/Makefile.msp430`.
10. In `cpu/msp430/Makefile.msp430`, because we do not use IAR, it defaults to GCC. It then sets the compiling toolchain to the gcc msp430 cross compiler. As:

cpu/msp430/Makefile.msp430

```
114 GCC      = 1
115 CC       = msp430-gcc
116 LD       = msp430-gcc
117 AS       = msp430-as
118 AR       = msp430-ar
119 NM       = msp430-nm
120 OBJCOPY  = msp430-objcopy
121 STRIP    = msp430-strip
122 BSL      = msp430-bsl
```

11. Sets source file searching path `vpath`.

Two pattern rules set every target two prerequisits at the end of this file:

Makefile.include

```
269 # Cancel the predefined implict rule for compiling and linking
270 # a single C source into a binary to force GNU make to consider
271 # the match-anything rule below instead.
272 %: %.c
273
274 # Match-anything pattern rule to allow the project makefiles to
275 # abstract from the actual binary name. It needs to contain some
276 # command in order to be a rule, not just a prerequisite.
277 %: %.$(TARGET)
278         @
```

The first pattern rule does not have a recipe. The purpose is to cancel the implicit rule. The second pattern rule has an empty recipe. The purpose here seems to not generate the real target but to make sure the prerequisit `z1-websense.z1` being generated.

As `CUSTOM_RULE_LINK` is defined near the end of `Makefile` so the rules for target `z1-websense.z1` on line 253 is defined and executed because `CUSTOM_RULE_LINK` has not been defined here yet.

```
253 %.$(TARGET): %.co $(PROJECT_OBJECTFILES) $(PROJECT_LIBRARIES) contiki-$(TARGET).a
254         $(TRACE_LD)
255         $(Q)$(LD) $(LDFLAGS) $(TARGET_STARTFILES) ${filter-out %.a,$^} \
256             ${filter %.a,$^} $(TARGET_LIBFILES) -o $@
```

The target `z1-websense.z1` is the final target, so the recipe in this rule is for linking object files. Note that it places archives to the last of all prerequisites when linking. This rule has several dependencies. We explain each one.

First one is `%co`. This is a pattern and it has its own pattern rule:

```
235 %.co: %.c
236         $(TRACE_CC)
237         $(Q)$(CC) $(CFLAGS) -DAUTOSTART_ENABLE -c $< -o $@
```

This pattern rule compiles the object files from C source files. So in this example, it compiles the object file `z1-websense.co` from `z1-websenso.c`. Please note that this rule defines a macro `AUTOSTART_ENABLE` as its compiling argument. This enables the autostart processes in the `z1-websense.c` to be defined as not empty. For further explanations, please see section 4.3.

The second one is `PROJECT_OBJECTFILES`. This is defined as:

```
87 PROJECT_OBJECTFILES = ${addprefix $(OBJECTDIR)/,${call oname, $(PROJECT_SOURCEFILES)}}
```

where `oname` is a variable defined as:

```
83 oname = ${patsubst %.c,%.o,${patsubst %.S,%.o,$(1)}}
```

which means substitute any file `n.c` or `n.S` to `n.o`. As we defined `PROJECT_SOURCEFILES=httpd-simple.c`, we then have `PROJECT_OBJECTFILES=obj_z1/httpd-simple.o`. Then we use the pattern rule:

```
226 %.o: %.c
227         $(TRACE_CC)
228         $(Q)$(CC) $(CFLAGS) -c $< -o $@
```

to compile `httpd-simple.c` to `obj_z1/httpd-simple.o`. As `httpd-simple.c` is not in the current directory, `make` uses the search path defined in `vpath` to find it. Actually it is in `examples/ipv6/rpl-border-router`.

But in `cpu/msp430/Makefile.msp430` this variable is appended as:

```
162 PROJECT_OBJECTFILES += ${addprefix $(OBJECTDIR)/,$(CONTIKI_TARGET_MAIN:.c=.o)}
```

The `:.c=.o` part is called a substitution reference to variables, which is actually an abbreviation for use of the `patsubst` expansion function. `CONTIKI_TARGET_MAIN` is defined in `platform/z1/Makefile.common` as:

```
24 CONTIKI_TARGET_MAIN = contiki-z1-main.c
```

File `contiki-z1-main.c` is under `platform/z1`. So `PROJECTFILES` actually has two files: `httpd-simple.o` and `contiki-z1-main.o`. They will be put in directory `obj_z1`.

The third one is `PROJECT_LIBRARIES`. This cannot be found anywhere. So it is empty.

The fourth one is `contiki-z1.a`. This is an archive file with its own rule:

```
243 contiki-$(TARGET).a: $(CONTIKI_OBJECTFILES)
244         $(TRACE_AR)
245         $(Q)$(AR) $(AROPTS) $@ $^
```

where `CONTIKI_OBJECTFILES` is defined as:

```
87 CONTIKI_OBJECTFILES = ${addprefix $(OBJECTDIR)/,${call oname, $(CONTIKI_SOURCEFILES)}}
```

The variable `CONTIKI_SOURCEFILES` is defined and appended in multiple files. We list the definitions in the order they appear.

In `example/z1/ipv6/z1-websense/Makefile`:

```
13 CONTIKI_SOURCEFILES += wget.c
```

In `core/net/rime/Makefile.rime`:

```
19 CONTIKI_SOURCEFILES += $(RIME_BASE) \
20                 $(RIME_SINGLEHOP) \
21                 $(RIME_MULTIHOP) \
22                 $(RIME_MESH) \
23                 $(RIME_COLLECT) \
24                 $(RIME_RUDOLPH) \
25                 $(RIME_CHAMELEON) \
26                 $(RIME_UIP6)
```

In `core/net/mac/Makefile.mac`:

```
1 CONTIKI_SOURCEFILES += cxmac.c xmac.c nullmac.c lpp.c frame802154.c sicslowmac.c nullrdc.c nullrdc-n
2 CONTIKI_SOURCEFILES += framer-nullmac.c framer-802154.c csma.c contikimac.c phase.c
```

In `core/net/rpl/Makefile.rpl`:

```
1 CONTIKI_SOURCEFILES += rpl.c rpl-dag.c rpl-icmp6.c rpl-timers.c \
2         rpl-mrhof.c rpl-ext-header.c
```

In `Makefile.include`:

```
73   CONTIKIFILES = $(SYSTEM) $(LIBS) $(NET) $(THREADS) $(DHCP) $(DEV)
```

```
78 CONTIKI_SOURCEFILES += $(CONTIKIFILES)
```

```
104   CONTIKI_SOURCEFILES += $(APP_SOURCES) $(DSC_SOURCES)
```

In cpu/msp430/Makefile.msp430:

```
44 CONTIKI_SOURCEFILES        += $(CONTIKI_TARGET_SOURCEFILES)
```

So contiki-z1.a is the system library and contains most of the system files of Contiki.

The final process for the target is:

```
msp430-gcc -Wl,--defsym -Wl,__P1SEL2=0x0041 -Wl,--defsym -Wl,__P5SEL2=0x0045 \
-mmcu=msp430f2617 -Wl,-Map=contiki-z1.map -Wl,--gc-sections,--undefined=_reset_vector__,\
--undefined=InterruptVectors,--undefined=_copy_data_init__,--undefined=_clear_bss_init__,\
--undefined=_end_of_init__  z1-websense.co obj_z1/httpd-simple.o obj_z1/contiki-z1-main.o \
    contiki-z1.a  -o z1-websense.z1
```

The linker deletes intermediate files after successfully linking. We can keep those files for debugging purposes. Just use those files as prerequisites for the special target .SECONDARY.

Both obj_z1/httpd-simple.o and obj_z1/httpd.o contain the function symbol httpd_init, but because the latter is archived in the file contiki-z1.a, this symbol is resolved to the object file httpd-simple.o. Also because the latter is an archive file, the linker won't report a multiple definition error like when detecting identical symbols in multiple object files.

3.4.2 Uploading to a Z1 mote

The rule for uploading to a Z1 mote is %.upload. It is defined in platform/z1/Makefile.common as:

```
94 %.upload: %.ihex
95         cp $< $(IHEXFILE)
96         @echo $(MOTES)
97         $(MAKE) z1-reset z1-upload
```

The prerequisite is defined in cpu/msp430/Makefile.msp430 as:

```
187 %.ihex: %.$(TARGET)
188         $(OBJCOPY) $^ -O ihex $@
```

Intel HEX (ihex) is a file format that conveys binary information in ASCII text form. It is commonly used for programming microcontrollers, EPROMs, and other types of programmable logic devices. In a typical application, a compiler or assembler converts a program's source code (such as in C or assembly language) to machine code and outputs it into a HEX file. The HEX file is then imported by a programmer to "burn" the machine code into a ROM, or is transferred to the target system for loading and execution[4].

These rules show that the `z1-websense.ihex` file is generated using `msp430-objcopy`, and this file is copied to `tmpimage.ihex` for flashing.

The variable `MOTES` is the device name for the mote. We can specify it when operating a specific mote, for example:

```
make z1-websense.upload MOTES=/dev/ttyUSB0
```

3.4.3 TUNSLIP6

The tool `tunslip6` is used to connect the border router to the outside world. As we run `make connect-router` it actually executes:

```
23        sudo $(CONTIKI)/tools/tunslip6 aaaa::1/64
```

The `tunslip6` is compiled from `tools/tunslip6.c`. Let's analyze this file. It does such things:

1. Sets default parameters: baud rate as 115200, no flow control.
2. Parses command-line options and set parameters accordingly. Like baud rate, host name, device file, etc.
3. As we do not provide host address here (unlike in Cooja), it tries to open `/dev/ttyUSB0` by calling `devopen`.
4. Calls `stty_telos` to set parameters for the opened serial device.

4 Movement detection on Z1 motes

4.1 ADXL345 accelerometer

The ADXL345 accelerometer is produced by Analog Devices. It is a small, thin, ultralow power, 3-axis accelerometer with high resolution (13-bit) measurement at up to ±16 g.

ADXL345 has several interrupts that look interesting. There are single tap and double tap interrupts, and a free fall interrupt that is generated when there is a free fall detected, also activity and inactivity interrupts for detecting moving and non-moving. The registers and interrupts are defined as:

platform/z1/dev/adxl345.h

```
186 /* Reference definitions, should not be changed */
187 /* adxl345 slave address */
188 #define ADXL345_ADDR            0x53
189
190 /* ADXL345 registers */
191 #define ADXL345_DEVID           0x00    // read only
192 /* registers 0x01 to 0x1C are reserved, do not access */
```

```
193 #define ADXL345_THRESH_TAP      0x1D
194 #define ADXL345_OFSX            0x1E
195 #define ADXL345_OFSY            0x1F
196 #define ADXL345_OFSZ            0x20
197 #define ADXL345_DUR             0x21
198 #define ADXL345_LATENT          0x22
199 #define ADXL345_WINDOW          0x23
200 #define ADXL345_THRESH_ACT      0x24
201 #define ADXL345_THRESH_INACT    0x25
202 #define ADXL345_TIME_INACT      0x26
203 #define ADXL345_ACT_INACT_CTL   0x27
204 #define ADXL345_THRESH_FF       0x28
205 #define ADXL345_TIME_FF         0x29
206 #define ADXL345_TAP_AXES        0x2A
207 #define ADXL345_ACT_TAP_STATUS  0x2B    // read only
208 #define ADXL345_BW_RATE         0x2C
209 #define ADXL345_POWER_CTL       0x2D
210 #define ADXL345_INT_ENABLE      0x2E
211 #define ADXL345_INT_MAP         0x2F
212 #define ADXL345_INT_SOURCE      0x30    // read only
213 #define ADXL345_DATA_FORMAT     0x31
214 #define ADXL345_DATAX0          0x32    // read only, LSByte X, two's complement
215 #define ADXL345_DATAX1          0x33    // read only, MSByte X
216 #define ADXL345_DATAY0          0x34    // read only, LSByte Y
217 #define ADXL345_DATAY1          0x35    // read only, MSByte X
218 #define ADXL345_DATAZ0          0x36    // read only, LSByte Z
219 #define ADXL345_DATAZ1          0x37    // read only, MSByte X
220 #define ADXL345_FIFO_CTL        0x38
221 #define ADXL345_FIFO_STATUS     0x39    // read only
222
223 /* ADXL345 interrupts */
224 #define ADXL345_INT_DISABLE     0X00    // used for disabling interrupts
225 #define ADXL345_INT_OVERRUN     0X01
226 #define ADXL345_INT_WATERMARK   0X02
227 #define ADXL345_INT_FREEFALL    0X04
228 #define ADXL345_INT_INACTIVITY  0X08
229 #define ADXL345_INT_ACTIVITY    0X10
230 #define ADXL345_INT_DOUBLETAP   0X20
231 #define ADXL345_INT_TAP         0X40
232 #define ADXL345_INT_DATAREADY   0X80
```

While checking the map file, we find that the ADXL345 interrupts use vector addresses `0xFFE4`. The interrupt service routine `ISR` is defined as:

cpu/msp430/isr_compat.h

```
63 #define ISR(a,b) interrupt(a ## _VECTOR) b(void)
```

After macro expansion, it becomes

```
interrupt(PORT1_VECTOR) port1_isr(void)
```

This is an MSPGCC extension. The macro `PORT1_VECTOR` is defined in file `msp430f2617.h` provided by msp430-libc.

```
#define PORT1_VECTOR        (0x0024) /* 0xFFE4 Port 1 */
```

There are two paramters for the free fall detection: minimal time threshold and maximal acceleration threshold. When at rest, the accelerometer measures 1g acceleration towards the ground, and in a free falling, the acceleration is 0.

The `FREE_FALL` bit is set when acceleration of less than the value stored in the `THRESH_FF` register (Address 0x28) is experienced for more time than is specified in the `TIME_FF` register (Address 0x29) on all axes (logical AND). The `FREE_FALL` interrupt differs from the inactivity interrupt as follows: all axes always participate and are logically ANDed, the timer period is much smaller (1.28 sec maximum), and the mode of operation is always dc-coupled.

The default free fall time in Contiki 2.7 is 160 ms. The default free fall threshold is 563 mg, also defined in `platform/dev/adxl345.h`.

```
167 #define ADXL345_THRESH_FF_DEFAULT       0x09    // 563 mg
168 #define ADXL345_TIME_FF_DEFAULT         0x20    // 160 ms
```

The free fall interrupt service routine is called `accm_ff_cb`. This is a callback function. It will be called after a free fall interrupt. Before using them we need to first register them. For example, in `examples/z1/test-adxl345.c`:

```
181     /* Register the callback functions for each interrupt */
182     ACCM_REGISTER_INT1_CB(accm_ff_cb);
183     ACCM_REGISTER_INT2_CB(accm_tap_cb);
```

The macro `ACCM_REGISTER_INT1_CB` actually points the function pointer `accm_int1_cb` to the function `accm_ff_cb`:

platform/z1/dev/adxl345.h

```
129 /* Macros for setting the pointers to callback functions from the interrupts.
130   The function will be called with an uint8_t as parameter, containing the interrupt
131   flag register from the ADXL345. That way, several interrupts can be mapped to
132   the same pin and be read from the  */
133 #define ACCM_REGISTER_INT1_CB(ptr)    accm_int1_cb = ptr;
134 #define ACCM_REGISTER_INT2_CB(ptr)    accm_int2_cb = ptr;
```

The function pointer `accm_int1_cb` is defined in the accelerometer driver file `platform/dev/adxl345.c`.

The basic process of accelerometer in `examples/z1/test-adxl345.c` in the process `accel_process`:

```
165 PROCESS_THREAD(accel_process, ev, data) {
166   PROCESS_BEGIN();
```

```
167   {
168     int16_t x, y, z;
169
170     serial_shell_init();
171     shell_ps_init();
172     shell_file_init();  // for printing out files
173     shell_text_init();  // for binprint
174
175     /* Register the event used for lighting up an LED when interrupt strikes. */
176     ledOff_event = process_alloc_event();
177
178     /* Start and setup the accelerometer with default values, eg no interrupts enabled. */
179     accm_init();
180
181     /* Register the callback functions for each interrupt */
182     ACCM_REGISTER_INT1_CB(accm_ff_cb);
183     ACCM_REGISTER_INT2_CB(accm_tap_cb);
184
185     /* Set what strikes the corresponding interrupts. Several interrupts per pin is
186       possible. For the eight possible interrupts, see adxl345.h and adxl345 datasheet. */
187     accm_set_irq(ADXL345_INT_FREEFALL, ADXL345_INT_TAP + ADXL345_INT_DOUBLETAP);
188
189     while (1) {
190             x = accm_read_axis(X_AXIS);
191             y = accm_read_axis(Y_AXIS);
192             z = accm_read_axis(Z_AXIS);
193             printf("x: %d y: %d z: %d\n", x, y, z);
194
195       etimer_set(&et, ACCM_READ_INTERVAL);
196       PROCESS_WAIT_EVENT_UNTIL(etimer_expired(&et));
197     }
198   }
199   PROCESS_END();
200 }
```

1. Initialize the accelerometer by calling `accm_init`.
2. Register the interrupt callback functions.
3. Call `accm_set_irq` to enable free fall, tap, and double tap interrupts in ADXL345.
4. Read the X, Y, Z axis readings each second continuously.

We need to send the free falling events to the Internet by 6LoWPAN.

4.2 Main architecture

For the movement detection, we decide to implement it based on the Z1 websense code and ADXL345 test code. The Z1 websense is a simple web server running on top of the IPv6 contiki stack on Z1

motes to provide sensor values, and with a RPL border router to bridge the sensor network to Internet. The C source file is `examples/z1/ipv6/z1-websense.c`.

The ADXL345 test code is used for testing the functionality of ADXL345 under Contiki.

We thus take out the ADXL345 test code and add it to the Z1 websense file to make the accelerometer reading can be visited on the web server. We remove the serial shell from the ADXL345 test code as it is too big to fit in the ROM after combining two modules. We do not need to change the makefile.

After compiling and linking, a MSP430 ELF file called `z1-websense.z1` will be generated. Let's first analyze this file.

There are some initialization code at first (mostly provided by the compiler), then it jumps to the `main` function provided by `platform/z1/contiki-z1-platform.c`. From the `main` function, all the processes and kernel functions are scheduled, and device drivers loaded.

4.3 Code implementation

There are 3 processes in the movement detection code. They are `web_sense_process`, `accel_process`, and `status_process`. They are automatically started after booting the motes.

examples/z1/ipv6/z1-websense.c

```
57 PROCESS(web_sense_process, "Sense Web Demo");
58 PROCESS(accel_process, "Test Accel process");
59 PROCESS(status_process, "Status handling process");
60
61 AUTOSTART_PROCESSES(&web_sense_process, &accel_process, &status_process);
```

The definition of `web_sense_process` process' thread is:

```
159 PROCESS_THREAD(web_sense_process, ev, data)
160 {
161   static struct etimer timer;
162   PROCESS_BEGIN();
163   cc2420_set_txpower(31);
164
165   sensors_pos = 0;
166   process_start(&webserver_nogui_process, NULL);
167
168   etimer_set(&timer, CLOCK_SECOND * 2);
169   SENSORS_ACTIVATE(battery_sensor);
170   SENSORS_ACTIVATE(temperature_sensor);
171
172   while(1) {
173     PROCESS_WAIT_EVENT_UNTIL(etimer_expired(&timer));
174     etimer_reset(&timer);
175
176     battery1[sensors_pos] = get_mybatt()*1000;
177     temperature[sensors_pos] = get_mytemp();
```

```
178       sensors_pos = (sensors_pos + 1) % HISTORY;
179     }
180
181     PROCESS_END();
182   }
```

This process:

1. calls `cc2420_set_txpower` to set the radio transmission power.
2. starts another process `webserver_nogui_process` that sets up the web server.
3. activates the battery and temperature sensors.
4. gets the values of the battery and temperature sensors every 2 seconds.

The `main` function mainly:

1. Initializes the MSP430 CPU and all peripheral devices.
2. Starts all autostart processes by calling `autostart_start`. It further calls `process_start` for each autostart process.
3. Starts the scheduler loop.

4.4 ADXL345 sensor processing

Use interrupts to detect falling, moving. ADXL345 calculates the vector sum of all 3 axes and compares the vector sum with predefined thresholds. We use 313mg for the maximal acceleration and 160ms for the minimal duration.

The function `process_poll` is used to set the flag `needspoll` in the PCB. Polling is the way to make a process run from an interrupt. The `process_poll` function is the only function in the process module that is safe to call from preemptive mode[5].

core/sys/process.c

```
370 void
371 process_poll(struct process *p)
372 {
373   if(p != NULL) {
374     if(p->state == PROCESS_STATE_RUNNING ||
375        p->state == PROCESS_STATE_CALLED) {
376       p->needspoll = 1;
377       poll_requested = 1;
378     }
379   }
380 }
```

To send the status information to the web server, we modify the callback functions of the interrupts to add status information:

examples/z1/ipv6/z1-websense.c

```
/* accelerometer free fall detection callback */

void
accm_ff_cb(uint8_t reg){
  status = "FALL";
  process_post(&status_process, status_event, NULL);
  printf("~~[%u] Freefall detected! (0x%02X) -- ", ((uint16_t) clock_time())/128, reg);
  print_int(reg);
}
/*---------------------------------------------------------------------------*/
/* accelerometer tap and double tap detection callback */

void
accm_tap_cb(uint8_t reg){
  process_post(&status_process, status_event, NULL);
  if(reg & ADXL345_INT_DOUBLETAP){
    status="RUNNING";
    printf("~~[%u] DoubleTap detected! (0x%02X) -- ", ((uint16_t) clock_time())/128, reg);
  } else if(reg & ADXL345_INT_TAP){
    status="WALKING";
    printf("~~[%u] Tap detected! (0x%02X) -- ", ((uint16_t) clock_time())/128, reg);
  } else{
    status="MOVING";
    printf("~~[%u] Move detected! (0x%02X) -- ", ((uint16_t) clock_time())/128, reg);
  }
  print_int(reg);
}
```

We also use y axis values to detect sitting and standing. We think the user is standing if $y < -200$, sitting if $y > -100$. The 3 axes values are read constantly every second.

examples/z1/ipv6/z1-websense.c

```
    while (1) {
      x = accm_read_axis(X_AXIS);
      y = accm_read_axis(Y_AXIS);
      z = accm_read_axis(Z_AXIS);
      //      printf("x: %d y: %d z: %d\n", x, y, z);
      if(strncmp(status,"",1) == 0){
        if(y < -200){
          process_post(&status_process, status_event, NULL);
          status = "STANDING";
        }
        if(y > -100){
          process_post(&status_process, status_event, NULL);
          status = "SITTING";
        }
      }
      etimer_set(&et, ACCM_READ_INTERVAL);
      PROCESS_WAIT_EVENT_UNTIL(etimer_expired(&et));
    }
```

4.5 Web communication

A mote connects to the Internet through the border router. The ideal way to communicate with the web server on the Internet is to send an HTTP request packet whnever a certain movement is detected. But as sending HTTP request has not be fully implemented, we resort to a hack (courtesy to Tolga) that exploits the `<img>` tag. We use Tolga's web server for this purpose.

```
<img src="http://tolgazeybek.ddns.net:8083/
?devicename=Zengxu&status=STATUS">
```

The implementation is to modify the html header to let it refresh every 3 seconds to auto reload the new sensor status:

examples/z1/ipv6/z1-websense.c

```
91 static const char *TOP = "<html><head><meta http-equiv=\"refresh\" content=\"3\"><title>Contiki Web
```

and the `generate_chart` function to point to our web server:

examples/z1/ipv6/z1-websense.c

```
100 static void
101 generate_chart(void)
102 {
103   blen = 0;
104   ADD("<img src=\"http://tolgazeybek.ddns.net:8083/?"
105       "devicename=Zengxu&"
106       "status=%s",
107       status);
108   ADD("\">");
109 }
```

4.6 Memory map

For MSP430 MCUs, the addressable memory space is 128 KB. As per the hardware manual, all MSP430 devices with more than 64 KB memory has a MSP430X core.

A rough map of MSP430F2617:

RAM: `0x1100-0x30FF`. Flash: `0x3100-0x19FFF`.

The interrupt vector space is `0xFFC0-0xFFFF`. The reset vector is `0xFFFE`.

Because the limited memory in Z1 motes, be sure to check your code not to exceed the memory limit. Your code can sometimes be optimized if it is too large. The website of Contiki introduces several methods for code optimization.

4.7 Compile and running

We need to first flash the MAC addresses of our motes. For example:

```
make clean
make burn-nodeid.upload nodeid=158 nodemac=158
make z1-reset && make login
```

Every mote should have a unique address.

Then we flash the border router.

```
cd examples/ipv6/rpl-border-router
make TARGET=z1 savetarget
make border-router.upload
make connect-router
```

A virtual network interface `tun0` will be created.

Then, under the contiki virtual machine, open a terminal, run:

```
cd contiki/examples/z1/ipv6/z1-websense
make TARGET=z1 savetarget
make z1-websense.upload
make z1-reset && make login
```

This flashes the Z1 mote that is used for movement detection and runs the application.

4.8 Falling detection patterns

A real falling is a movement that has a distinct pattern[1]. There are 4 stages in a falling movement as shown in the 4 red boxes in Figure 3.

1. Start of the fall: The vector sum of acceleration will be significantly less than 1 g.
2. Impact: After experiencing weightlessness, the human body will impact the ground or other objects. There will be a large spike of acceleration.
3. Aftermath: After falling, there will generally be a period of motionless.
4. Comparing before and after: After a fall, the individual's body will be in a different orientation than before, so the static acceleration in three axes will be different from the initial status before the fall.

We can get a more accurate falling detection algorithm if we can use all the above information.

4.9 Virtual machine settings for USB

Below is my configuration under Linux. If you use Windows or Mac OS X host operating systems, the configuration of VirtualBox will be slightly different. Please consult the VirtualBox user manual on their website.

You need to be in the `vboxusers` group to be able to auto detect USB devices in VirtualBox. Run:

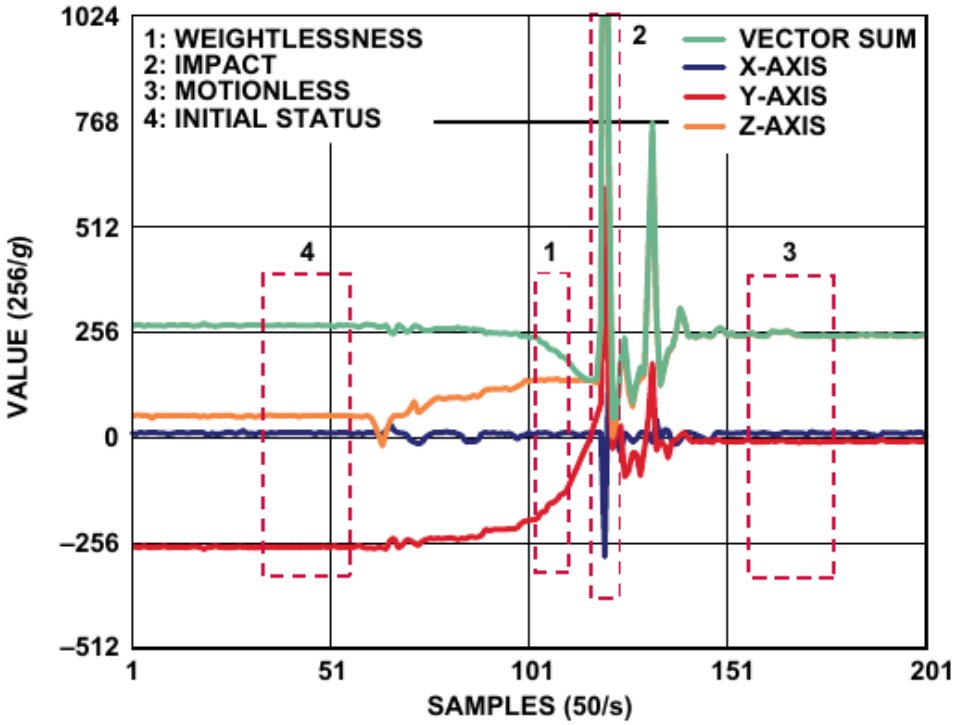

Figure 3: Falling Detection

```
sudo adduser yourname vboxusers
```

Log out and log in again.

If you need USB 2.0 support, you need to install Oracle VM VirtualBox Extension Pack.

Start VirtualBox, in "Settings-USB", enable USB by checking "Enable USB controller". Then click the icon with a small plus sign and then choose the "Silicon Labs Zolertia Z1 (0107)". This is the USB device for the Z1 motes. VirtualBox can use it after it is in the USB filter list.

4.10 Flash the Z1 mote through USB

Start your Contiki virtual machine with Z1 mote connected by a USB cord. The Z1 mote USB port is a simulated serial port with device file named usually `/dev/ttyUSB0`. Open a terminal and add yourself to the `dialout` group to have writable access to the USB serial device. Run:

```
sudo adduser user dialout
```

Then log out and log in to make it effect.

Open a terminal in Contiki virtual machine, run:

```
cd contiki/examples/hello-world
```

```
make hello-world.upload
```

If you see the lights in your mote flash then the image should be successfully burned into the Z1 mote.

5 Web server

This is for installing web service on the Contiki virtual machine which runs Ubuntu Linux 12.04. The following steps provide a working environment. As this is the simplest way of making sure everything works smoothly without worrying about different operating systems and configurations, compiling, priviledges problems, etc.

5.1 Install Tomcat

To install Tomcat, make sure your computer is connected to the Internet, then open a terminal and run:

```
sudo apt-get update
sudo apt-get remove openjdk-6*
sudo apt-get install openjdk-7-jdk
sudo apt-get install tomcat7 tomcat7-admin tomcat7-examples
```

Edit the Tomcat user configuration file with

```
sudo nano /etc/tomcat7/tomcat-users.xml
```

and add the following before the last line:

```
<role rolename="manager-gui"/>
<user username="twl" password="twl" roles="manager-gui"/>
```

Then run

```
sudo service tomcat7 restart
```

to restart the Tomcat 7 service.

Launch the firefox browser and enter `localhost:8080`. If everything is OK you will see the welcome page of Tomcat. Then you can click the link “manager webapp” under “tomcat7-admin” in this page. When asked about user name and password, type “twl” and “twl”.

In the `/manager` page you can deploy your program by using “WAR file to deploy”.

5.2 PostgreSQL database

1. Install PostgreSQL and JDBC driver:

   ```
   sudo apt-get install postgresql libpostgresql-java-jdbc
   ```

2. Create a password for the PostgreSQL database:

   ```
   sudo -u postgres psql
   \password
   ```

3. Log into the PostgreSQL database using the password just created:

   ```
   psql -U postgres -h localhost
   ```

4. After logging into PostgreSQL, create a table:

   ```
   CREATE TABLE devices (device_id integer NOT NULL, UNIQUE(device_id),
    user_name varchar(40), protocol varchar(80));
   ```

5. If your created table is not what you want, you can drop it.

   ```
   DROP TABLE devices;
   ```

Do not forget putting a semicolon after each command.

5.3 Deploy Ruiling's program

After installing Tomcat and PostgreSQL database, you can start deploying Ruiling's program and registering your new devices.

1. Download Ruiling's program named `my_web_app.war` which is a compressed Java web archive to a directory and extract it.
2. Edit the file `dbcheck.jsp` and change the password to the one that you just created:

   ```
   connection = DriverManager.getConnection(
                "jdbc:postgresql://localhost:5432/postgres",
                "postgres", "password");
   ```

3. Still in the extracted directory, copy the installed JDBC driver to the web app by running:

   ```
   cp /usr/lib/java/postgresql-jdbc4-9.1.jar WEB-INF/lib
   ```

4. Delete and repackage the WAR file:

   ```
   rm my_web_app.war
   jar -cvf my_web_app.war *
   ```

5. In your browser, go to `localhost:8080/manager` and deploy the newly generated WAR file. You will then be able to add devices to the database from your browser.

6 CoAP

Constrained Application Protocol (CoAP) is a software protocol intended to be used in very simple electronics devices that allows them to communicate interactively over the Internet. It is particularly targeted for small low power sensors, switches, valves and similar components that need to be controlled or supervised remotely, through standard Internet networks. CoAP is an application layer protocol that is intended for use in resource-constrained internet devices, such as WSN nodes. CoAP is designed to easily translate to HTTP for simplified integration with the web, while also meeting specialized requirements such as multicast support, very low overhead, and simplicity[6].

The CoRE group has designed CoAP with the following features in mind:

- RESTful protocol design minimizing the complexity of mapping with HTTP.
- Low header overhead and parsing complexity.
- URI and content-type support.
- Support for the discovery of resources provided by known CoAP services.
- Simple subscription for a resource, and resulting push notifications.
- Simple caching based on max-age.

The mapping of CoAP with HTTP is also defined, allowing proxies to be built providing access to CoAP resources via HTTP in a uniform way.

7 Problems and planned improvement

- The IMG hack we use is awkward and slow. The delay can be 5 to 6 seconds and the new sensor information could be lost while waiting for the page refreshment. We plan to use direct HTTP requests instead of the IMG hack. This requires us to write HTTP requests using TCP communication. The IMG hack is awkward and slow.
- There is an interrupt sharing problem prevents us from using more interrupts other than the 3 interrupts provided in the test code. Debug and solve the interrupt sharing problem.
- The falling detection is simple and could be confused with other movements. Improve the detection algorithm to make it more accurate. The falling analysis in section 4.8 is a good direction.
- The web communication method used in our project is still crude. There are standards for more scalable and future proof ways. We plan to investigate CoAP method for RESTful web sensor management.

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Movement Detection using Contiki and Android
EE193 Project 1 Final Report
Part II

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1. Introduction

1.1 Eclipse IDE

The Eclipse IDE is the software required to coding JAVA language. It includes android tools shown below:

- Android studio IDE
- Android SDK tools
- Android 5.0 (Lollipop) Platform
- Android 5.0 emulator system image with Google APIs

At the core of Android Studio is an intelligent code editor capable of advanced code analysis. We are able to build apps for Android phones, tablet, Android Wear, Android TV, Android Auto and Google Glass. The Virtual Device Manager provides pre-defined device profiles for common Android. SDK Tools includes the complete set of development and debugging tools for the Android SDK.

1.2 Motorola Moto G XT1045

The Motorola Moto G XT1045 Tech specs is shown:

Motorola Moto G XT1045 Tech specs		
NETWORK	Technology	GSM / HSPA+ / EDGE / UMTS/ HSDPA / HSUPA / LTE
LAUNCH	Announced	2014, MAY
PLATFORM	OS	Android OS, v4.4.2 (KitKat), upgradable to v4.4.4 (KitKat)
	Chipset	Qualcomm MSM8226 Snapdragon 400
	CPU	Quad-core 1.2 GHz Cortex-A7
	GPU	Adreno 305
MEMORY	Internal	8 GB, 1 GB RAM
FEATURES	Sensors	Accelerometer, Proximity, Compass and Ambient Light
	Messaging	SMS(threaded view), MMS, Email, Push Email, IM
	Browser	HTML 5
	Jave	Yes, via Java MIDP emulator
BATTERY		Li-Ion 2070 mAh battery
	Standby	12600 minutes | 210 hours | 8.8 days

Motorola Moto G features a powerful accelerometer sensor, a long-life battery and a powerful quad-core processor. The accelerometer sensor provides the acceleration on x, y and z axis which are necessary values for analysing human behaviours. Plus, the 1.2 GHz quad-core CPU is able to compute the algorithm vary fast. In order to simulating the fall detector on Moto G XT1045, the programer should download Android 4.4.2 (API 19) packages from the Android SDK manager. (You can find the SDK manager in Eclipse at Windows->Android SDK manager)

1.3 ANDY Android Emulator

ANDY Android Emulator is a software which breaks down the barrier between desktop and mobile computing, which means this software lets apps run on the computer.

We use ANDY to run a sever APK file. Here, we did not actually build the sever on our computer, but use another one built by Tolga Zeybek. All of our data is sent to his server.

2. Project Network Configuration

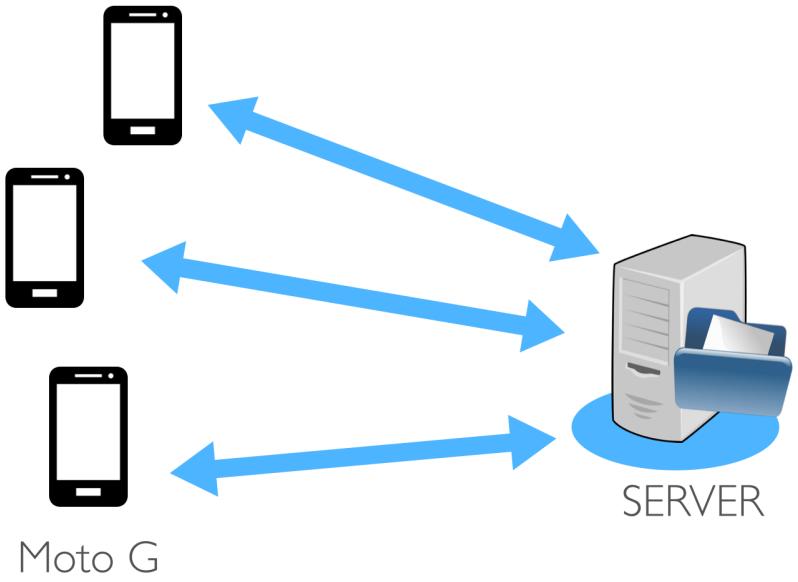


Figure 1.

In figure 1, the Moto G is able to talk to the server directly, and the server will save the data sent from Moto G.
The whole system includes:

1. A computer runs the android sever application on ANDY Android Emulator.
2. A Moto G runs the fall detector application.

P.S All the devices must connect to the internet.

The computer is installed the ANDY Android Emulator to run a sever APK, which are able to receive massages through the internet from any devices.

The code of the package sent from Moto G is shown in figure 2.

```
//http client stuff here:
String sendHttpRequest(String url, String devicename, String status)
{

    StringBuilder returnstring = new StringBuilder();

    StringBuilder design_url = new StringBuilder();

    try{
    design_url.append(url).append("/?devicename=").append(devicename).append("&status=").append(status);
    HttpURLConnection con = (HttpURLConnection) ( new URL(design_url.toString())).openConnection();
    con.setRequestMethod("POST");
    con.setDoInput(true);
    con.setDoOutput(true);
    con.connect();
    InputStream is = con.getInputStream();
    byte[] b = new byte[2];
    while ( is.read(b) != -1)
    {
      returnstring.append(new String(b));
      Log.w("inputstream",returnstring.toString());
    }
    con.disconnect();
    }catch(Exception e)
    {;

    }
    return returnstring.toString();
}
```

Figure 2. The code of the sending package. (The code is provided by Tolga Zeybek.)

The package includes the device name, status of the user, client IP and the uploaded time. When the sever received the package, it will update it's data base. The data is shown in figure 3 and at http://tolgazeybek.ddns.net:8083/?item=less .

Record ID	Device Name	Status	Client IP	Timestamp
11485	motorola_XT1045_Tolga_Zeybek	sitting	130.64.22.2	December 15, 2014 at 18:02:14 EST
11484	motorola_XT1045_Tolga_Zeybek	small motion	130.64.22.2	December 15, 2014 at 18:02:09 EST
11483	motorola_XT1045_Tolga_Zeybek	walking	130.64.22.2	December 15, 2014 at 18:02:09 EST
11482	motorola_XT1045_Tolga_Zeybek	small motion	130.64.22.2	December 15, 2014 at 18:02:08 EST
11481	motorola_XT1045_Tolga_Zeybek	walking	130.64.22.2	December 15, 2014 at 18:02:06 EST
11480	motorola_XT1045_Tolga_Zeybek	small motion	130.64.22.2	December 15, 2014 at 18:02:03 EST
11479	OnePlus_A0001_Tolga_Zeybek	standing	130.64.194.8	December 15, 2014 at 17:56:08 EST
11478	OnePlus_A0001_Tolga_Zeybek	sitting	130.64.194.8	December 15, 2014 at 17:55:17 EST
11477	OnePlus_A0001_Tolga_Zeybek	User requested help.	130.64.194.8	December 15, 2014 at 17:55:16 EST
11476	OnePlus_A0001_Tolga_Zeybek	Fall verified by user.	130.64.194.8	December 15, 2014 at 17:55:08 EST
11475	OnePlus_A0001_Tolga_Zeybek	FALL	130.64.194.8	December 15, 2014 at 17:55:08 EST

Figure 3. The activity history (This is built by Tolga Zeybek)

3. The Fall Detector Algorithm

3.1 The accelerometer sensor

Accelerations on x, y and z axis are detected by the accelerometer sensor. These three value will be used for analysing the status of the user. Moreover, we are going to sum of these three dimension vector by the formula shown below:

$$sum\ of\ the\ vector = \sqrt{x^2 + y^2 + z^2}$$

3.2 The Thresholds

We set up 3 thresholds to define the weight of the acceleration values. The first threshold value is $5m^2/sec$,the second one is $16m^2/sec$ and the last one is $22m^2/sec$. The threshold value is changeable because the effect of the detector on each person will be different. The reason why we set 5, 16 and 22 is that it gives the best result from the experimental subject.

3.3 The Weight of The Data

In order to recognise the current human status, we give each value a weight. The value mentioned here is the sum of the vector. Sum of the vector, in other word, is the detected acceleration on the sensor. The code we use to define weight is shown in figure 4.

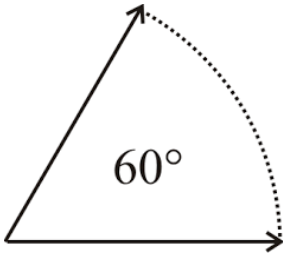
```
//weight define loop
private double weight_def(double[] window){
    int count=0;
    for(int i=1;i<=BUFF_SIZE-1;i++){
        if(window[i]>th1 && window[i]<th2){
            count=count+1;
        }
        else if(window[i]>th2 && window[i]<th3){
            count=count+3;
        }
        else if(window[i]>th3){
            count=count+100;
        }
        else
            count+=0;
    }
    return count;
}
```

Figure 4. The weight code

Window is an array which saves 50 values of sum of the vector. The parameters th1, th2 and th3 are the thresholds(5, 16, 22 sequentially). By comparing the data with thresholds, we are able to give each data a weight. In the code, if the data is less than 5, we do not add weight to

the data. If the data is bigger than 5 but less than 16, we add 1 to its weight. Moreover, if the data is between 16 and 22, we add 3. Last, if the data is over 22, we add 100 to the weight.

3.4 The Weight of Angle



If the angle between the Moto G and the ground is between 60 and 90 degrees, we add 3 to the angle's weight, otherwise, we add 1. This means the Moto G is currently at a vertical status. The formula we use here is the sin formula.

$$sin\theta = |y| / \sqrt{x^2 + y^2 + z^2}$$

The range of sin theta is between 0 and 1 because we set the y value as an absolutely value. The code of the weight of angle is shown in figure 5.

```
// define angle weight
private double compute_anglevalue(double[] savedangle2){
    int acount=0;
    for (int i=1;i<=BUFF_SIZE-1;i++){
        if(savedangle2[i]-signed_sin>=0){
            acount=acount+3;
        }
        else acount=acount+1;

    }
    return acount;
}
```

Figure 5. The code of the weight angle.

The parameter signed_sin is the value of sin(60) which is 0.866 and the savedangle2 is an array which saves the sin value of the data. This loop will compare each data to signed_sin and count the weight. In the end, the loop will return the total weight of the angle.

3.5 Define Human Activities

By checking the weight values we are able to define the activities of a person. The weight equals to zero we defines the current activity a static activity (which includes sitting and standing). The way we distinguish sitting and standing is by checking the gravity sensor. For example, if the gravity sensor says that the device is vertical, we are able to say that the user is standing. The code is shown in figure 6.

```
if(weight_sum==0){
    if(Math.abs(y)<9.8){
    curr_state="sitting";
    }
    else{
        curr_state="standing";
    }
}
```

Figure 6.

In addition to the static activity, dynamic activity is another state. Running and walking are the two statuses in this state. The way we distinguish running and walking is by comparing the weight. If the weight is bigger than 19, we define the current status is running. If the weight is between 19 and 1, we define the current states is walking. The code is shown in figure 7.

```
else if(weight_sum>0 && weight_sum<100){
    if(weight_sum>19 && weight_sum<100){
        curr_state="running";
    }
    else{
        curr_state="walking";
    }

}
```

Figure 7.

Last, if the weight is over 100, we define the current activity as an extremely dynamic activity (which includes jumping and falling). The method we used to distinguish jumping and falling is by checking the weight of angle. If the weight of angle is bigger than 110, we define it as a jump. Otherwise, it is a fall. The code is shown in figure 8.

```
else if(weight_sum>100){
    if(angle>110){
        curr_state="jumping";
    }
    else{
        curr_state="fall";
    }
}
```

Figure 8.

It will be easier to understand the algorithm by overlooking the structure shown in figure 9.

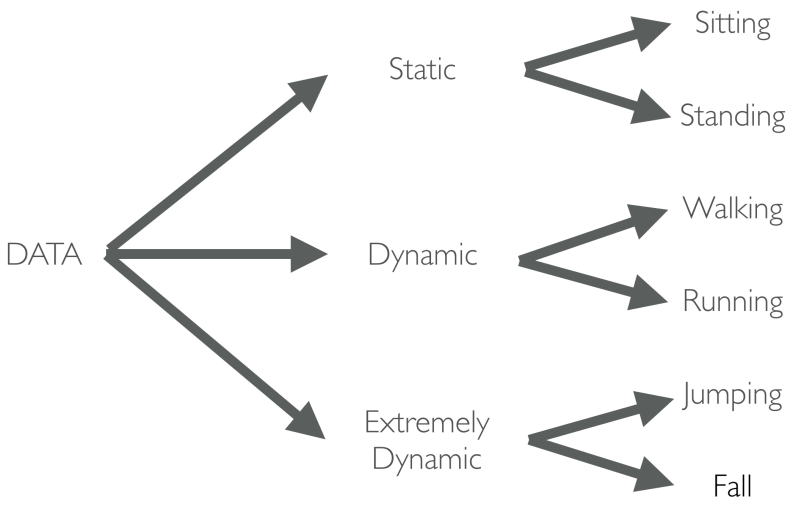


Figure 9.

4. Test and Result

On practical experiments, we test each statuses for 50 times. The result is shown below:

	Correct	Wrong	Ratio
Sitting	45	5	0.9
Standing	44	6	0.88
Walking	37	13	0.74
Running	34	16	0.68
Jumping	21	39	0.42
Fall	32	18	0.64

The way we test the sitting and standing is by alternating standing and sitting. The result is quit good. However, sometimes, when we stood up, the sensor detect it a jump because we stand up too fast. Also, when we are sitting down, if we sit too fast, the sensor will detect it a fall.

We also test the walking and running alternatively. During the walking, there is an acceleration when we turned our direction, which might let the sensor think we are running or jumping. Moreover, when we give it a heavy step, the sensor will consider it as a jump, this both happened on running and walking test. Besides, when we are testing running, sometimes it considered we are walking because we did not run fast enough.

Jumping is the most unstable status during the experiment. If we jump too frequently, the sensor might detect it as a running or walking. If the impact of the jump is too small, the result will be walking. Moreover, If we jump forward, sometimes it will consider it a fall. Jumping is the hardest activity to be defined. The solution is to tune the sensitivity of the sensor by machine learning.

The result of falling is not good as we expected. Probably the way we test it is wrong. We did not actually fall down, however, we threw the Moto G on the ground. The acceleration during the experiment might not close to the real fall sometimes. Therefore, sometimes it consider the situation as a jump or running.

5. Improvement In the Future

5.1. The activities are different from people to people.

The solutions is to embed Machine Learning system to tune the sensitivity personally. Because there is no best solution, the thresholds should be changed on different users and so does the other values. Therefore, the machine learning is necessary.

5.2. The environment will change.

The solution is to define dangerous areas and automatically change the sensitivity of the detector. For example, if the sensor detect the user get into the bathroom, it raise the sensitivity because the chance to fall in a bathroom is relatively high.

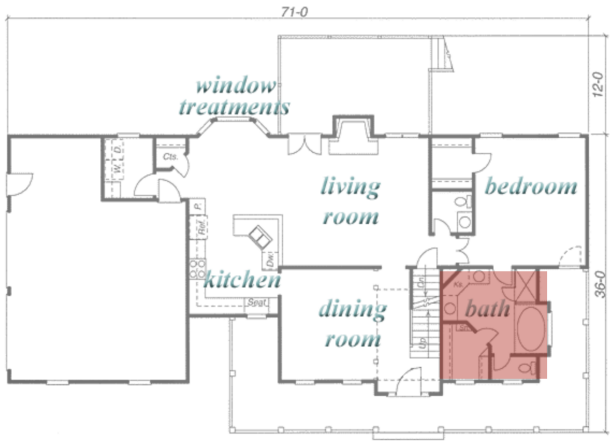


Figure 10. from DESAIN RUMAH UNIK(6)

To achieve this technology, we must add a detector to figure out user's location in order to change the sensitivity.

Moreover, if the user fall, the sensor will also be able to send back the location of the user, which might provide more help to handle the emergencies.

5.3 The sensor is not enough.

Combine with other sensors: Blood pressure, heart rate, steps, walking and running distance.

When a fall happened, the blood pressure and the heart rate will raise extremely. Even though running also raise the heart rate and blood pressure, but if we combine with the step sensor, we can easily tell it is a fall or running. For example, when we get high heart rate and high blood pressure, but the step sensor counted 7 step, it probably be running.

5.4 Barrier of our fall detector

The user must wear the sensor properly or the sensor will give a terrible work. The sensor is designed to put into the pants pocket and must be vertical. If the user hold it on the hand or put it in the bag, the sensor is not able to detect right.

To solve this problem, the sensor might be designed rotatable, it will automatically change its algorithm to detect the activities.

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